Towards a Cognitive Assistant System for Elderly

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ABSTRACT

This paper proposes the development of a system to integrally control the activities carried out by a group of elderly people in a nursing home. The system is basically composed of a robot and an app that proposes activities, and also an individual wristband that monitors each elderly person to detect if they get bored or have fun doing the activities. As commented, the system also includes an app that, among other things, allows the caregiver to monitor the activities of the group or in an individualized way.

Keywords: cognitive assistants, ageing, emotion detection.

2000 Mathematics Subject Classification: 68T40, 68T45, 68T99.

1 Introduction

Nowadays, we live in a society where people are living longer and longer thanks to medical advances and improved quality of life. In addition, roles in society have changed in recent decades, with women increasingly integrated into work outside the home. These advantages, however, bring with them a challenge that we must face as a society: unwanted loneliness in vulnerable groups such as the elderly.

As the population ages, there are more and more cases of people living alone and needing care, supervision and companionship. To help in these cases, one of the solutions that have increased in recent years are intelligent systems and assistive robots (Costa and Novais, 2012; Oliveira, Costa, Neves and Novais, 2013; Ramos, Costa, Novais and Neves, 2014). These robots can help both the family and the caregivers to assist the elderly. Such robots often include intelligent technologies such as voice synthesis (Miranda, 2004; Schröder, 2001), speech recognition (Graves, Mohamed and Hinton, 2013) and image recognition (Ng, Nguyen, Vonikakis and Winkler, 2015; Kahou, Pal, Bouthillier, Froumenty, Gülçehre, Memisevic, Vincent, Courville, Bengio, Ferrari et al., 2013) to facilitate interaction with people unfamiliar with new technologies. Since the target audience of this type of robotic assistants often has no skills

with technology, it is important to include interfaces that require artificial intelligence and little technological interaction such as conversational voice assistants. The technology required for this must be able to capture audio waves, transcribe them into text and interpret the meaning of the sentence. This also makes it possible to identify the person with whom one is interacting, and thus to personalize the assistance being provided. Some of these robots have locomotion mechanisms that allow them to move within the environment, others are table robots which behave like personal assistants.
Interaction between humans has an emotional component that is important to take into account, and historically, human-computer interactions did not include them. Currently some of these robotic assistants incorporate the ability to classify the emotional state of the person they are interacting with (Li and Lu, 2009; Yang, Lin and Chen, 2007; Mower, Mataric and Narayanan, 2010; Nwe, Wei and De Silva, 2001). In addition, being able to express emotions to interact with humans is also a feature developed by today's technologies. This management of emotions is a complex task where information must be obtained from the environment to interpret the emotion of the person with whom one interacts, thus modifying the decision making according to this emotion, and finally expressing also an emotional component. This feature, added to the previous ones, allow users to feel a closer affinity to the robot, as well as, to facilitate the interaction with it.
This paper tries to go deeper into this topic by proposing a system to facilitate the performance of activities by older people as well as their control for a correct performance of these activities. In this way, the proposed system is mainly formed by an assistant robot, called *EMiR*, capable of interacting with humans and to monitor and recommend physical activities to older people in a nursing home. Moreover, the system also includes individual wristbands that facilitate the acquisition of signals for detecting users' stress levels. Finally, an app allows caregivers and care-receivers to be informed about any progress in monitoring the activities carried out by the care-receivers.

2 Related Work

Given today's societal challenges, it is clear that current technological responses are not capable of addressing all physical and cognitive problems. One domain that tries to deal with these problems is robotics with the development of humanoid-shaped assistant robots that serve as company and help in everyday tasks.
There are currently several efforts to manufacture robots capable of assisting in various tasks or providing general information about ADL's. When aimed at older people these robots can be categorised into 3 topics: company, therapy and health (and tele-assistance). Depending on the subject they are aimed at, the robots have a pleasant appearance, a powerful background of artificial intelligence, navigation in complex environments, artificial vision, etc.

2.1 Company Robots

These robots are mostly designed to have a friendly (if possible, human-like) appearance and artificial intelligence abilities that allows them to have a fluid conversation with humans.

Martinez-Martin (Martínez-Martín and Cazorla, 2019; Martínez-Martín and del Pobil, 2018) identifies the following robots as domestic assistants, i.e. communication assistants: Pepper (Tanaka, Isshiki, Takahashi, Uekusa, Sei and Hayashi, 2015) and Romeo (Claudio, Spindler and Chaumette, 2016) from SoftBank, Aido[1] or Buddy from Blue Frog Robotics[2].

Pepper is a small robot with a almost human-like shape (from the torso up) that is able to communicate with people and is able to navigate in somewhat complex environment due to its spherical wheels. It has a high angle of limb and head rotation and is factory-equipped with a operating system that is able to maintain a simple conversation with people, responding to simple questions while performing certain actions (like breathing-like movements) that are similar to human movements, designed to create empathy. Apart form this, Pepper is able to follow people (accounting for obstacles) but is unable to carry weight, as it is equipped with low-force hand grippers, thus retrieving any object that is heavy (more than a glass of water) is impossible.

Romeo is a humanoid-robot developed by SoftBank designed to be the companion of the Pepper robot. In reality, it is a far more advanced robot, being biped and having newer and more accurate sensors. It is able to locate itself in the face of obstacles, to walk, to carry objects, to help humans get up, the objective being that it can ultimately be a robot assistance dependent people. It has RGB-D cameras that allows it to measure distances, it is also equipped with four computers to manage its sight, hearing, movements and artificial intelligence. Its main function is to help with everyday tasks, such as writing down and remembering appointments or medications to be taken, making a shopping list and finding lost glasses. With his computing power he is able to detect if the person has a fall and help them get up or call emergency services if necessary.

Aido is an endearing robot that will help in all household chores, with an innumerable list of features that it can offer you. Aido can be an alarm clock in the morning, a toy for children, and can protect the home. In addition, it uses a sphere to move around and can manoeuvre around complex spaces with furniture, and other minor obstacles at home. The robot incorporates a projector and speakers to teach movies and videos, it also has a facial recognition system and adapt its functions and activities to the preferences of the person with whom it shares its time. Aido has a basic cognitive system and is able to interact with people and answer simple questions (if connected to the internet) and manage the daily agenda.

Buddy has a height of 56 cm and a weight of 5 kg and is designed to express a range of emotions, while interacting with humans. It has a camera, various ultrasound sensors, infrared sensors, motion sensors, thermal sensors, and sensors that allow to calculate distances, as well as a microphone and speakers. It travels thanks to three wheels that are incorporated in its lower part that also allow it to rotate and move in different directions, and has touchscreen

[1] http://aidorobot.com/
[2] http://www.bluefrogrobotics.com/robot/

for interaction. Its software is open source and separate applications can be created. He can communicate in English and French. It can be used as a communication gateway, via video-messaging software. Like other robots it is able to respond to simple questions and establish a human-like interaction.

2.2 Therapy Robots

These robots aim is to proving psychological assistance rather than physical one. Most of them are designed to be hold and to enact as a pet or child, to trigger positive feelings on the users and help them cognitively. A well known example is the Paro robot.

Paro is an advanced interactive robot developed by AIST that looks like a seal. This aspect is used to take advantage of the benefits of animal therapy and is designed to be used by patients in hospital environments. This robot was built to accompany children and the elderly in an attempt to create a positive emotional response.

QTrobot from LuxAI (Costa, Charpiot, Lera, Ziafati, Nazarikhorram, Torre and Steffgen, 2018) is an interactive robot that helps autistic children by teaching them basic life and social skills. It is a standing robot (unable to move), has movable arms and head and is designed as a doll, of small stature and pleasurable looks. Validation results have discovered that autistic children show higher levels of attention, learn faster and are less conflicting with this robot. The robot has no relevant intelligent system and its tasks are selected remotely by a tutor, following strict successfully-proven pedagogic methods. Its main feature is a large screen that is used as a ”face” to show positive emotional reactions and to give visual descriptions and to play games.

2.3 Health Robots

These robots are designed to be a place-in medical assistant with features centred in health monitoring and tele-assistance. More than simple interaction, these robots are e-Health centred thus having more focused interaction procedures and less broad than its counterparts.

Mabu robot of Catalia Health[3] aims to learn about the personality, interests and therapeutic actions of each user. Thus, Mabu can create personalised conversations for each user. The structure of these conversations is based on classic behavioural models of psychology in order to promote behaviour change.

GrowMeUp's project objective is to implement a robotic system capable of providing medical care and improving the quality of life, with the aim of helping older people to stay in their homes independently (Georgiadis, Christophorou, Kleanthous, Andreou, Santos, Christodoulou and Samaras, 2016). The objective is to help carry out daily activities at home and, simultaneously,

[3]http://www.cataliahealth.com/introducing-the-mabu-personal-healthcare-companion/

protect, guide and interact with the elderly, connecting them with other people in their social and care networks. Its software is designed so that through interaction and observation learn the habits, preferences and routines of its user, making it possible to adapt its services over time. With a large number of sensors this is able to listen, speak, see and express emotional facial expressions and recognise humans and objects. The robot is equipped with two wheels and can move freely in horizontal planes. Finally, it is connected to a multi-agent network and can share information with other robot platforms.

Andago from Hocoma[4] is a mobile robot for body-weight supported gait training that allows upright, hands-free walking without spatial limitations. Its objective is to help recover people that suffered injuries and are at the rehabilitation phase. While this robot lacks any type of cognitive interaction (it does not have any type of communicative interfaces) it has a large set of sensors that sense the user's movements and adjusts its motors and weights to accommodate to specific rehabilitation programmes.

These projects show that these are several robots that address a multitude of domains related to cognitive and/or physical assistance, having an underlying impact, being advanced and the target of a careful development. Unfortunately, they often lack in terms of functionality and most of them are very expensive. Also, they usually express emotion but are unable to perceive accurately the ones displayed by humans, nor they are personalised to each individual. Our project aims to cover these issues while maintaining a low purchase value.

3 System Description

This section describes our proposal for a system which is a continuation of a previous research presented in (Rincon, Costa, Novais, Julian and Carrascosa, 2018). This new research incorporates a series of devices capable of classifying movements and emotions, as well as having the ability to communicate with a robot which accompanies the person during the exercise. All these new parts complement the existing mobile app for the care-givers and care-receivers.
Wearable devices and accompanying robots are quickly introduced into our society. This is mainly due to the low cost of these new tools. This low cost allows today to have bracelets capable of measuring cardiac signals as photoplethysms (PPG), Galvanic Skin Response (GSR) and robot assistants used as accompaniment and therapy systems. These new tools have powerful systems that allow the capture of information from users, different communication protocols that make them compatible with different IoT platforms. In our wristband the three signals mentioned above are acquired by means of three communication protocols: WiFi, Bluetooth and LoRa. On the other hand, the assistant robot has different elements that allow to monitor the environment and the people who use it. The robot is able to classify emotional states, it has a direct communication with the wristband as well as, the capacity to recognize commands by voice and navigation.
To make this application possible it is necessary to integrate different types of hardware that facilitate the acquisition of signals (physiological and movement), human interaction tools for

[4]https://www.hocoma.com

the robot, software tools that analyze the information sent by the devices. Thus, mixing these technologies, it is possible to recognize patterns in the movements, make recommendations and / or use the bio-signals acquired in telemedicine and detect patients' stress levels. In the following subsections, a detailed description of the different elements that make up the wristband and the assistant robot, along with a description of the mobile-apps for care-givers and care-receivers will be made.

3.1 Wristband Description

We have devised a set of two elements to carry out the monitoring of physical activities. Two bracelets have been developed as shown in Figure 1.

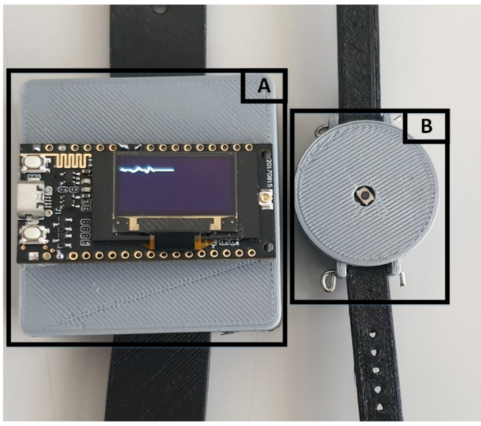


Figure 1: Wristband (A) and Motion detector (B) prototypes.

Both bracelets allow us to detect the physical activity of people, however bracelet *A* has a more complex composition compared to *B*. Although both bracelets have an accelerometer and a gyroscope (3-axis), which detect the movements made by the user in space (Figure 2). Bracelet *A* is the master bracelet, this means that bracelet *B* sends its sensor data to bracelet *A*. This sends the data from its own sensors and the data from bracelet *B* to the robot and/or to a mobile phone application. One of the advantages of using a master bracelet is the ability to add other bracelets that allow us to monitor the user's lower extremities or chest. At the same time, the A-bracelet is responsible for obtaining the PPG and GSR signals, these two signals are used to detect stress levels.
The detection of the stress levels are made using the PPG and GSR signals, the sensors used to make the acquisition of these signals are shown in the Figure 3. Several studies have successfully linked changes in heart rate variability to stress. Taelman et.al (Taelman, Vandeput, Spaepen and Van Huffel, 2009) studies have identified how stress alters some physiological factors and how the autonomic nervous system is activated. These changes lead to changes in heart rate, as well as heart rate variation. Hjortskov et.al (Hjortskov, Rissén, Blangsted, Fallentin, Lundberg and Søgaard, 2004) made experiments in a stressful work environment, where they measured how the work activity affected the heart frequency. These investigations show how the heart frequency varies according to the environments. On the other hand, it is

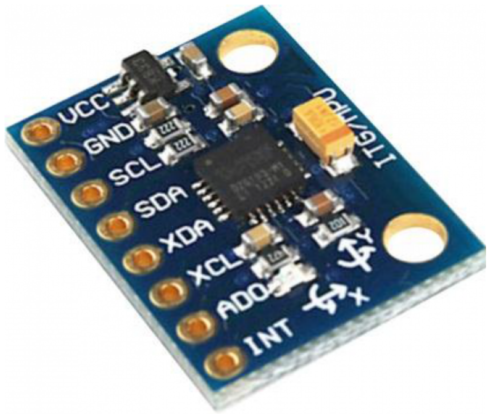
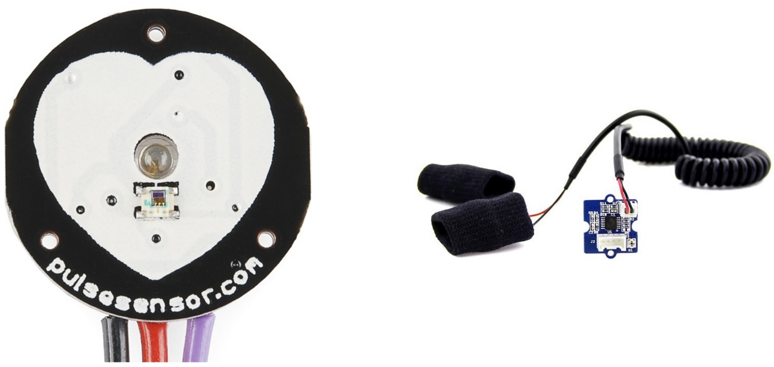


Figure 2: Sensor MPU6050 using to measure the physical activity.

also possible to determine stress levels using a GSR (Navea, Buenvenida and Cruz, 2019) sensor. By integrating these two stress detection methods, it is possible to improve stress detection during physical activity. The sensors used to detect stress levels are shown in the Figure 3. The first sensor (*a*) is the photoplethysmography sensor, this makes a beam of light pass over the skin, to make the subcutaneous vessels light up. This makes a part of this ray reflect, falling on a photo-transistor that converts it into an equivalent voltage. Because the skin absorbs more than 90% of the light, the system incorporates amplifiers and filters that ensure an adequate voltage. The second sensor (b) is a sensor that records the GSR signal, only two electrodes are required for this recording. GSR is based on the assumption that skin resistance varies with the state of the sweat glands in the skin. It is for this reason that this device injects a small voltage through the electrodes connected to the skin. If there is a strong stimulus the activity of the sweat glands changes. This change is reflected in the increased conductance of the skin, and vice-versa. This increase or decrease makes the small voltage that has been injected vary, this variation is then amplified and suitable for further processing.



(a) Photoplethysmography sensor

(b) GSR sensor

Figure 3: Photoplethysmography and GSR sensor.

The analog signals returned by the sensors are digitized using the ESP-32's analog to digital converter. Our system uses an ESP-32 ttgo development system (Figure 4), which is being widely used in IoT applications. This is mainly due to its easy programming and to the fact that it has WiFi, LoRa and Bluetooth communication protocols with low power consumption or BLE. These features make this device the ideal tool to be used in monitoring applications.

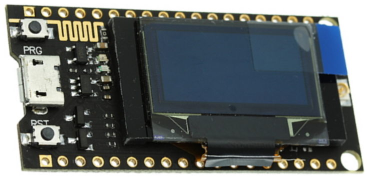


Figure 4: ESP-32 ttgo Developer Board.

Once the different signals have been captured by the respective sensors, it is necessary to adapt these signals and make the respective conversions for further processing. To carry out this process, it was decided to use an *ESP-32-TTGO*. This device has the communication protocols previously mentioned (*WiFi, LoRa and Bluetooth low power consumption*), as well as two Analog to Digital Converters (*ADCs*). These ADCs of 10 bit resolution, allow to convert the analog signals coming from the sensors to a digital signal, which is stored in a memory register *EEPROM* (Electrically Erasable Programmable Read-Only Memory). In this register are stored 30 seconds of PPG and GSR information, the data coming from the accelerometers and gyroscopes are sent in raw every 30 ms. Once the 30 seconds of information is stored, the device calculates the pulses-per-minute in an average way. That is, it counts the amount of peaks (R-R Interval at Figure 5) that exist in the signal and multiplies it by 2, in this way it is possible to estimate the pulses-per-minute of the person.

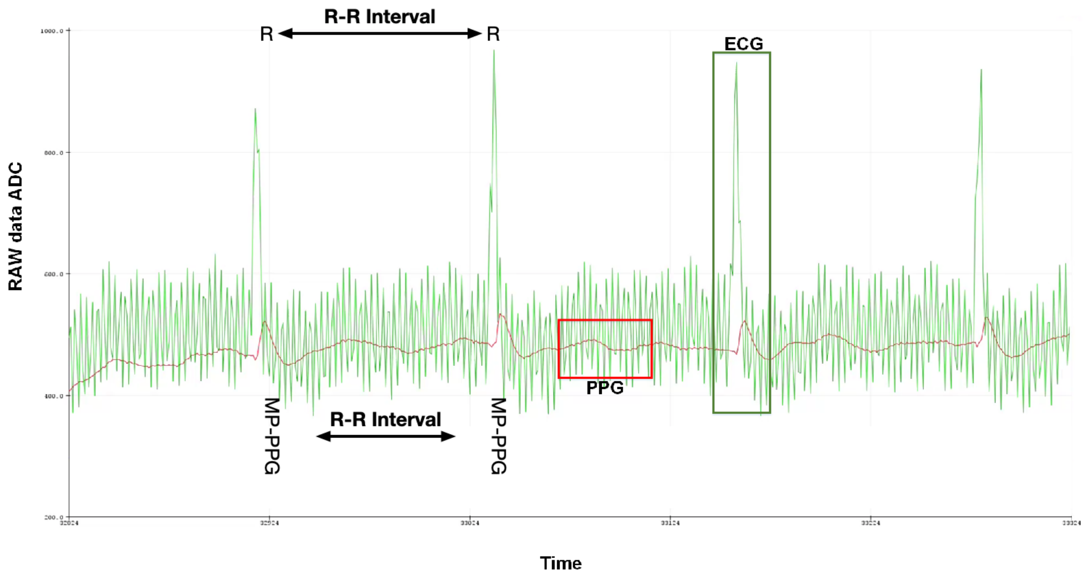


Figure 5: Comparison between the ECG and PPG signal to calculate the pulses per minute.

3.2 Robot Description

EMiR is a low-cost robot designed to monitor and recommend physical activities to older people. This robot was built using a Raspberry-pi 3 b+, a 7-inch LCD screen, a frontal camera, motors for its locomotion and ultrasound sensors for obstacle detection. Figure 6 shows the *EMiR* prototype.

Figure 6: *EMiR* prototype.

EMiR has the ability to classify emotional states, using his front camera. To perform the classification of emotions using images, it uses the KDEF database and tensorflow lite. The database contains a total of 4900 pictures of human facial expressions. The set of pictures contains 70 individuals displaying 7 different emotional expressions (Afraid, Angry, Disgusted, Happy, Neutral, Sad, Surprised). Each expression is viewed from 5 different angles. To carry out the classification of emotions it is necessary to carry out a series of intermediate steps, the first of which is to resize the image obtained by the camera. In this way you go from an image of 640x480 pixels to an image of 48x48 pixels. It must be taken into account that this process is carried out due to the memory and processor limitations of the raspberry. Once this has been done, the next step is the extraction of the face. This is carried out in order to eliminate the background noise from the image. In order to classify the seven emotions, a three-layer neural network was created. The structure of the network can be seen in the Figure 7.
As well as the *EMiR* can classify emotions, he can express emotions using the LCD screen. *EMiR* can express 7 emotions, these are shown in the following Figure 8.

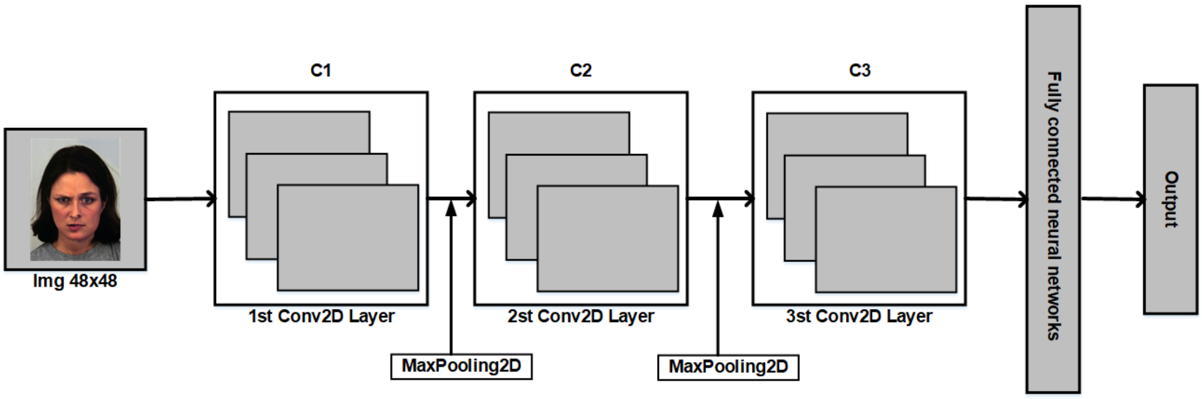


Figure 7: Convolutional Neural Network (CNN) Structure.

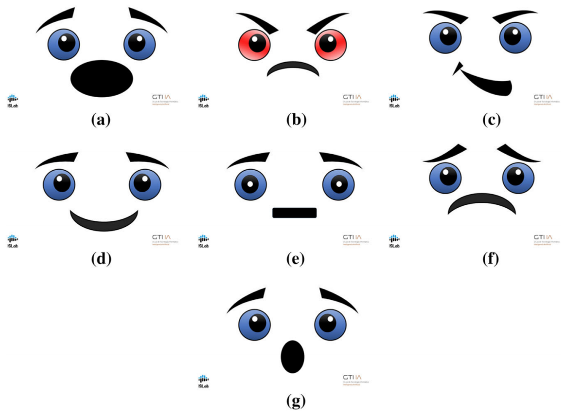


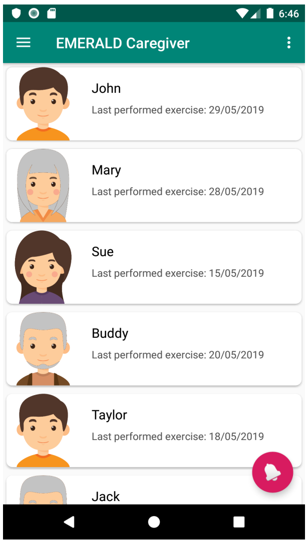
Figure 8: *EMiR* face draft. a Robot afraid face, b Robot angry face, c Robot disgusted face, d Robot happy face, e Robot neutral face, f Robot sad face, g Robot surprised face.

3.3 App Description

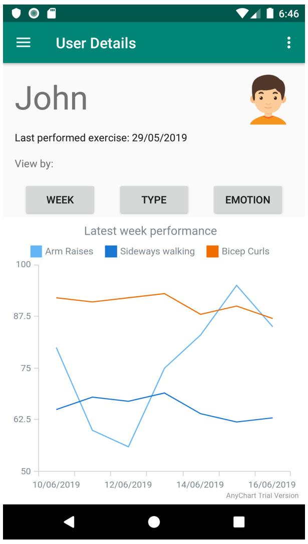
The care-receivers and the caregivers can directly interact with the system via an Android application. This application is designed to be easy to use by the users and an extension to the wristband sensors and the robot. In fact, due to the responsibility and tasks of each type of user (care-receivers and caregivers) two applications were designed.

3.3.1 Caregiver

The caregivers application contains information about each person the caregiver is monitoring (Figure 9(a)). Upon selection of one care-receiver, the caregiver is able to view detailed information about its activity performance. In Figure 9 (b) is shown the user photo, a brief detail about the activity performance (the last date of activity), and the statistics of the activities. The statistics are divided into graphs that show the week, type and emotion values. The week graph shows the performance values of each activity over a one week period. With this information the caregivers are able to detect a decay in performance, which may be signs of health problems.



(a) List of care-receivers the caregiver is monitoring.



(b) Care-receivers information and time-related statistics.

Figure 9: Caregiver view of the APP

The type graph shows the performance divided by the type, in a bar-chart. Each activity belongs to one (or more) group of activities (Sitting, Flexibility, Strength, Balance) and is designed to strengthen the care-receivers in specific body areas. The aim of this graph is to show the progression of the care-receiver in each group, allowing the caregiver to view if the care-receiver is improving over time. The bar-chart displays the average performance value of the last two months.
The emotions graph displays the emotional evolution of the care-receiver, showing in a scale the emotions that were detected when performing each activity. It is used a bar-chart graph that is grouped by session, displaying each bar the emotion intensity.
Figure 10 shows the settings menu. In settings the caregiver may change the notification options (such as enable for only some care-receivers).

3.3.2 Care-receiver

The care-receiver has a completely different interface from the caregiver. While it displays some of the same information (short activity summary) the rest of the information is focused more on the activities than on the user. Furthermore, this application is designed to be a companion of the sensors system, being the data receptor of them. Figure 11(a) shows the welcome screen. The care-receiver is greeted and a short summary of the performance is displayed. This is done in an effort to motivate the care-receiver to keep performing the suggested activities. Apart form this, the *number of points* is also displayed. This feature is not yet implemented fully, but the aim is to introduce gamification to further engage the users in the activity program.
Bellow the summary part, it is displayed the activity schedule for the day. These are selectable

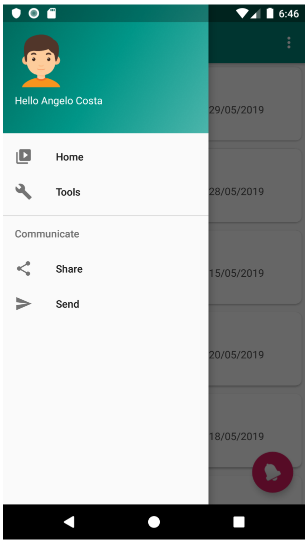
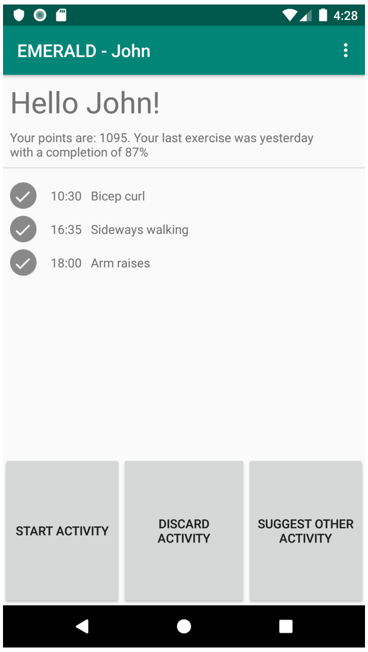
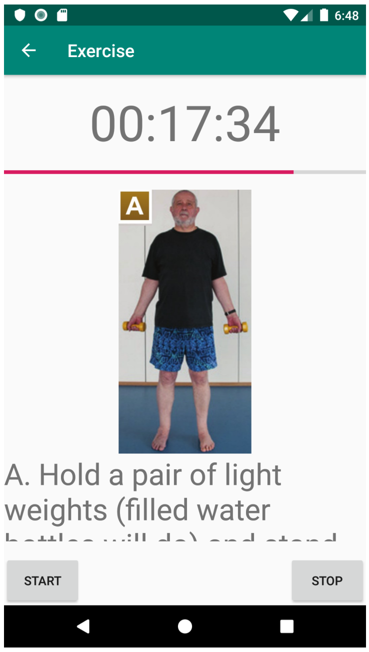


Figure 10: Caregiver settings menu.

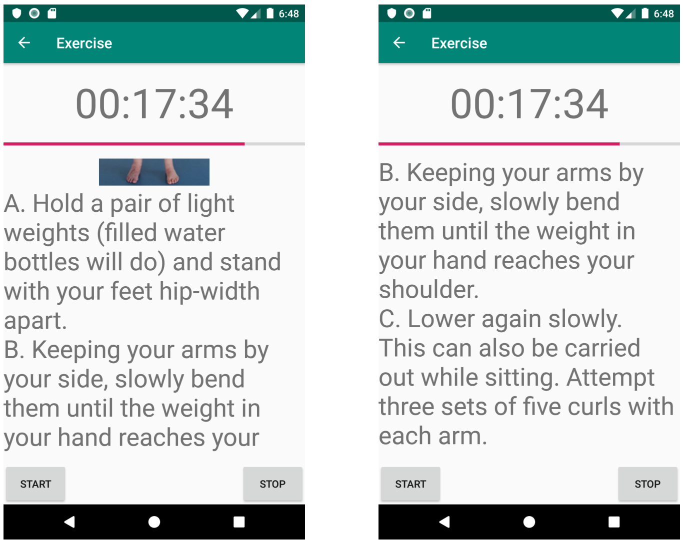


(a) Care-receiver android interface. It displays a salutation, a short statistics summary, the daily activity plan and buttons to accept/discard/suggest activities.



(b) Exercise guidance screen (1 of 3).

Figure 11: Care-receiver view of the APP (1)



(a) Exercise guidance screen (2 of 3).

(b) Exercise guidance screen (3 of 3).

Figure 12: Care-receiver view of the APP (2)

items that, with the use of the buttons in the bottom part of the screen, can be started, discarded, or traded for other activity. These actions are conveyed to the caregiver to inform about the progress/likes of the care-receivers. If the users select *discard activity* this activity will be removed from the schedule and this action will be delivered to the caregiver for further investigation. The *suggest other activity* prompts the App for other activity to replace the selected ones. The App will try to maintain the suggestion according to the caregiver specifications (typically one exercise that is in the same group of exercises). When start activity is pressed the care-receiver will be directed to the screen shown in Figures 11(b) to 12.

In Figures 11b to 12 the care-receiver is presented with a three part screen. The top part displays the time remaining for performing the activity. This is done to prevent the care-receivers of overdoing activities (even if the care-receiver has not fully completed the activity upon reaching maximum time a notification to rest is displayed). Below is the progress bar that displays the completeness of the activity. This information is originated from the App and the sensors that analyse continuously the activity performance.

In the middle part the activity guide is displayed. The screen is set on auto-scrolling mode so that the care-receiver does not have to interrupt the activity midway performing it. The guide provides useful information about on how to correctly perform these activities (body position) and number of repetitions and rest times. In the bottom part of the screen there are two buttons for starting and stopping the activity. These buttons are used mostly to synchronise the application with the information of the sensors and the App server. Apart from this, if the button *stop* is pressed, the care-receiver is guided to the previous screen and the information summary is updated in accordance to the activity performed.

4 Conclusions

In this work we have presented a cognitive assistant for older people which is formed by different components with the main objective of proposing and controlling the performance of activities by the elderly. The proposed system integrates a low-cost robot which monitors and recommends physical activities for a group of people and an intelligent wristband which analyses non-invasive bio-signals for the detection of physical activities and human emotional states. Apart from the development of the wristbands and the robot, care-receivers and the caregivers can directly interact with the system via an APP designed to be easy to use by the users as an extension to the wristband sensors and robot actions. The main application domain of the designed system is the elderly care in nursing homes, but it can be used in other types of domains.

The proposed approach is being validated by workers and patients of a daycare centre *Centro Social Irmandade de São Torcato*. The validation is being performed through simple activities with the patients under the supervision of caregivers. Future work will initially focus on the development of new tests with a larger number of users. These new tests will allow the system to be used to improve the activities and tasks performed at the centre in order to avoid situations where older people have undesirable emotional states.

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References

Claudio, G., Spindler, F. and Chaumette, F. 2016. Vision-based manipulation with the humanoid robot Romeo, *2016 IEEE-RAS 16th International Conference on Humanoid Robots (Humanoids)*, IEEE, pp. 286–293.

Costa, A. and Novais, P. 2012. Mobile sensor systems on outpatients, *International Journal of Artificial Intelligence* **8**(S12): 252–268.

Costa, A. P., Charpiot, L., Lera, F. R., Ziafati, P., Nazarikhorram, A., Torre, L. V. D. and Steffgen, G. 2018. More attention and less repetitive and stereotyped behaviors using a robot with children with autism, *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, IEEE.

Georgiadis, D., Christophorou, C., Kleanthous, S., Andreou, P., Santos, L., Christodoulou, E. and Samaras, G. 2016. A robotic cloud ecosystem for elderly care and ageing well: The GrowMeUp approach, *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*, Springer International Publishing, pp. 919–924.

Graves, A., Mohamed, A.-r. and Hinton, G. 2013. Speech recognition with deep recurrent neural networks, *2013 IEEE international conference on acoustics, speech and signal processing*, IEEE, pp. 6645–6649.

Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U. and Søgaard, K. 2004. The effect of mental stress on heart rate variability and blood pressure during computer work, *European journal of applied physiology* **92**(1-2): 84–89.

Kahou, S. E., Pal, C., Bouthillier, X., Froumenty, P., Gülçehre, Ç., Memisevic, R., Vincent, P., Courville, A., Bengio, Y., Ferrari, R. C. et al. 2013. Combining modality specific deep neural networks for emotion recognition in video, *Proceedings of the 15th ACM on International conference on multimodal interaction*, ACM, pp. 543–550.

Li, M. and Lu, B.-L. 2009. Emotion classification based on gamma-band eeg, *2009 Annual International Conference of the IEEE Engineering in medicine and biology society*, IEEE, pp. 1223–1226.

Martínez-Martín, E. and Cazorla, M. 2019. A socially assistive robot for elderly exercise promotion, *IEEE Access* **7**: 75515–75529.

Martínez-Martín, E. and del Pobil, A. P. 2018. Personal robot assistants for elderly care: An overview, *in* N. P. Costa A., Julian V. (ed.), *Personal Assistants: Emerging Computational Technologies*, Vol. 132 of *Intelligent Systems Reference Library*, pp. 77–91.

Miranda, E. R. 2004. Expressivity of voice synthesis by emphasizing source signal features. US Patent 6,804,649.

Mower, E., Mataric, M. J. and Narayanan, S. 2010. A framework for automatic human emotion classification using emotion profiles, *IEEE Transactions on Audio, Speech, and Language Processing* **19**(5): 1057–1070.

Navea, R. F., Buenvenida, P. J. and Cruz, C. D. 2019. Stress detection using galvanic skin response: An android application, *Journal of Physics: Conference Series*, Vol. 1372, IOP Publishing, p. 012001.

Ng, H.-W., Nguyen, V. D., Vonikakis, V. and Winkler, S. 2015. Deep learning for emotion recognition on small datasets using transfer learning, *Proceedings of the 2015 ACM on international conference on multimodal interaction*, ACM, pp. 443–449.

Nwe, T. L., Wei, F. S. and De Silva, L. C. 2001. Speech based emotion classification, *Proceedings of IEEE Region 10 International Conference on Electrical and Electronic Technology. TENCON 2001 (Cat. No. 01CH37239)*, Vol. 1, IEEE, pp. 297–301.

Oliveira, T., Costa, A., Neves, J. and Novais, P. 2013. A comprehensive clinical guideline model and a reasoning mechanism for aal systems, *International Journal of Artificial Intelligence* **11**(A13): 57–73.

Ramos, J., Costa, A., Novais, P. and Neves, J. 2014. Interactive guiding and localization platform, *International Journal of Artificial Intelligence* **12**(1): 63–78.

Rincon, J. A., Costa, A., Novais, P., Julian, V. and Carrascosa, C. 2018. Intelligent wristbands for the automatic detection of emotional states for the elderly, *in* H. Yin, D. Camacho, P. Novais and A. J. Tallón-Ballesteros (eds), *Intelligent Data Engineering and Automated Learning – IDEAL 2018*, Springer International Publishing, Cham, pp. 520–530.

Schröder, M. 2001. Emotional speech synthesis: A review, *Seventh European Conference on Speech Communication and Technology*.

Taelman, J., Vandeput, S., Spaepen, A. and Van Huffel, S. 2009. Influence of mental stress on heart rate and heart rate variability, *4th European conference of the international federation for medical and biological engineering*, Springer, pp. 1366–1369.

Tanaka, F., Isshiki, K., Takahashi, F., Uekusa, M., Sei, R. and Hayashi, K. 2015. Pepper learns together with children: Development of an educational application, *2015 IEEE-RAS 15th International Conference on Humanoid Robots (Humanoids)*, pp. 270–275.

Yang, C., Lin, K. H.-Y. and Chen, H.-H. 2007. Emotion classification using web blog corpora, *IEEE/WIC/ACM International Conference on Web Intelligence (WI'07)*, IEEE, pp. 275–278.